THE ELECTRIC CHARACTERISTICS OF THUNDERSTORMS AND LIGHTNING DISCHARGES ON THE TIBETAN PLATEAU

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Abstract: The electric characteristics of thunderstorms in July 2003 on the central Tibetan Plateau with an altitude of 4500 m above sea level was studied by using the data from field mill, slow antenna system, fast antenna system and VHF radiation pulse location. The thunderstorm is usually accompanied with hail fall and the surface electric field underneath thunderstorm usually shows the same polarity as clear sky. The cloud-to-ground discharge takes about 21.6% of all lightning discharges. The characteristics of both negative cloud-to-ground and intracloud lightning discharges suggest the polarity-inverted charge structure of thunderstorm on the Tibetan Plateau.

Key Words: Thunderstorm, Surface Electric field, Lighting discharge, Tibetan Plateau

1. Introduction

The mean elevation of Tibetan Plateau is higher than 4500m above sea level (asl) and shows unique circulation, weather phenomena and climate characteristics. The Plateau is usually covered by active cumulus convection, and thunderstorms, hailstorms and showers occur frequently in the summer season[1]. Qie et al. [2] analyzed the spatial and temporal distribution of lightning activity on the plateau by using the Lightning Imaging Sensor data. In this paper we present the first surface measurement of electric characteristics of thunderstorms and the lightning discharges on the Tibetan Plateau by using the ground-based measurements.

2. Observation Site and Instruments

The observation area is located in the central Tibetan Plateau (31°28'47"N, 92°03'39.8"E) with an altitude of 4508 m asl. During the observation, surface electric (E) field of thunderstorm and E field changes caused by the lightning discharge were measured by using field mill, slow antenna system with a time constant of 6 s and fast antenna system with a time constant of 2 ms, respectively. The signals from both slow and fast antennas were digitized at a sampling frequency of 2.5 MHz, and then automatically recorded in a PC.

A short-baseline lightning VHF pulse location system with Time Of Arrival (TOA) technique was employed during the observation. The working frequency is 280 MHz with a bandwidth of 6 MHz. The base line between each pair of the four dipole-antennas is 10 m. The signals from each antenna were digitized by a LeCroy374L oscillograph working at a segment pattern, and recorded in a PC through a GPIB card. The sampling rate for each channel is 2 GS/s. The two dimensional development of lightning discharge were determined from this system.

3. Results

3.1 Surface electric field underneath thunderstorm

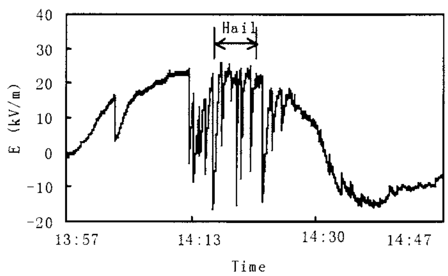

Fig.1 Surface E field for thunderstorm on July 7, 2003. The polarity of E field is defined as positive when it points downward.

During July 2003, a total of 14 thunderstorms and 551 lightning discharges were recorded. Among them 6 storms passed over the observation site. The surface E field showed positive for all the overhead thunderstorms. Figure 1 shows the surface E field for thunderstorm on July 7, 2003. It is interesting to note that all the 6 overhead thunderstorms were hailstorms with pea-size hailstones observed on the surface. The hail fall usually lasted not longer than 10 minutes. The average flash rate of thunderstorm is 1.1 fl/min, while that is 2.1 fl/min during the hail fall period. This suggests that there is a large positive charge region at the lower part of the storm, and the hails or graupels at the base of the cloud is very important to the positive surface E field. Table 1 presents the statistical results for all the overhead thunderstorms in July.

Table 1 Flash rate during thunderstorms in July, 2004

Date	Storm Duration (min)	Total Flash	CG	IC	+CG	Flash rate (fl/min)	Flash rate during hail fall (fl/min)	CG flash with continue current
Jul 3	124	97	38	59	0	0.8	2.6	15
Jul 7	101	117	3	114	0	1.2	3.6	0
Jul 8	111	112	30	82	0	1.0	2.0	13
Jul 10	120	138	43	95	0	1.1	1.6	5
Jul 14	47	65	5	60	0	1.4	1.4	0
Jul 26	22	22	0	22	0	1.0	1.2	0
Total		551	119 (21.6%)	432 (78.4%)	0			38 (27.7%)
Average						1.1	2.1	

3.2 Lightning activity

Among the 551 lightning discharges, 119 were cloud-to-ground (CG) discharges and the remaining 432 were intracloud (IC) discharges. The occurrence percentage of the CG discharges is 21.6%, which is much lower than that for the summer thunderstorms in Pampa La Bola, Chile with an altitude of 5000 m asl reported by Watanabe et al.[3]. No positive CG discharges were observed in July.

By analyzing the electric field data obtained with the slow antenna system, it was found that almost all the CG discharges are preceded by a long duration of IC discharges. Figure 2 shows an example. The IC discharge just before the CG discharge lasts about 237 ms, and the immediately followed CG discharge includes 4-return strokes marked by R1-R4. The mean duration of the long-duration of IC discharges is about 161.4 ms with a maximum of 600 ms, which is similar to the usual IC discharge. Because of the large amount of positive charge at the lower part of the storm, the negative CG flashes can only occur after the lower positive charge was partly neutralized. The lower positive charge region effects as a screen layer to the negative CG discharge which occurs between the upper negative charge region and the ground.

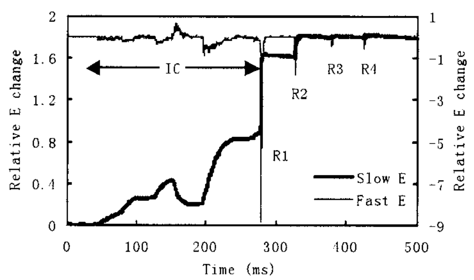

Fig 2 Surface E field changes produced by a CG lightning discharge occurred at 16:56:24 on July 8, 2003.

3.3 Return stroke and continuous current

The maximum stroke number per negative CG flash was 20 and the 50% value was 3. The 50%

value of interstroke time interval was 50.4 ms with a minimum of 12 ms and a maximum of 344 ms. The multiplicity of negative CG lightning discharges in the Tibetan Plateau is similar to the usual value[4].

The negative CG discharges are sometimes accompanied by continuous current. The occurrence percentage of the continuous current on Tibetan Plateau was 27.7% with a mean duration of 116 ms, similar to that for the usual summer lightning discharges in lower and mid-latitude regions[5]. Although the continuous current is at the order of only several hundred amperes, it could neutralize a huge amount of charge due to its long duration.

Although the CG lightning has the similar return stroke number to the usual thunderstorm. The radiation field is relatively weak. The normalized radiation field to 100 km is about 2.42 V/m, which is more than two times smaller than that in the lower and mid-altitude region[6].

3.4 Intracloud discharges

According to the VHF radiation pulse location results of several IC discharges, the IC discharges on the Tibetan Plateau occur between the negative charge region and the lower positive charge region, and shows inverted-polarity. Figure 3 shows the VHF pulse location results for an IC discharge at 15:07 (LT) on July 8, 2004. The total discharge lasted about 300 ms. It initiated at the upper negative charge region and propagated vertically downward to the lower positive charge region. It developed with several branches at the lower level, and only few radiation events were observed at the higher level in the final stage of the discharge.

4. Conclusion and Discussion

The electric characteristics of thunderstorms and the lightning discharges on the Tibetan Plateau were analyzed in this paper. Follows are the main findings.

1. The thunderstorms are usually hailstorms on the Tibetan Plateau with a hail fall period of shorter than 10 minutes and the diameter of hailstone on the ground is less than 1 cm. The surface E field underneath thunderstorm was usually downward pointed on the Tibetan Plateau, which suggests that there are a large positive charge region at the lower part of Tibetan Plateau thunderstorms.

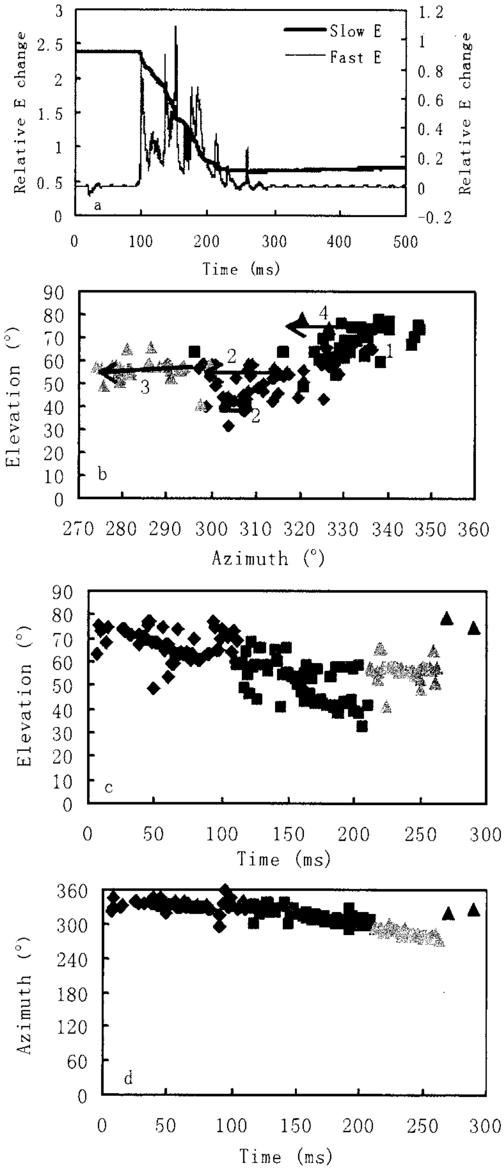

Fig. 3 VHF pulse location results by using TOA method for IC discharge at 15:07 (LT) on July 8, 2004. a: the fast and slow E-field changes, b: the 2-dimensional development of the discharge, c and d: the elevation and azimuth evolution of the discharge with time, respectively.

2. Most of the flashes are IC flashes which take about 78.4% of the total. Most of negative CG flashes follow long-duration of IC discharge that occurs between upper negative and lower positive charge region with a mean duration of about 161.4 ms. It suggests that negative CG can only occur after partly neutralized the lower positive charge region. This kind of phenomenon is similar to that in Chinese Inland Plateau [7], [8], [9].

3. Positive CG discharge is a relative rare event in the plateau region although the positive charge at the lower part of the cloud controls the surface E field. No positive lightning discharges were observed in July, but 7 were observed for two thunderstorms in August. The reason for the lower ratio of positive CG is remaining unanswered

4. The maximum number of strokes per CG flash is 20 with a 50% value of 3. The 50% value of the inter-stroke time interval is 50.4 ms; The occurrence percentage of continuous current is 23%. These characteristics are similar to the usual thunderstorm in the lower and mid-latitude.

5. The IC discharges show polarity-inverted structure, and it occurs between upper negative and lower positive charge region. The discharge initiates in the negative charge region and propagated vertically downward to the lower positive charge region. There are many radiation events and several branches at the lower positive charge region, while only few radiation events were observed at the higher negative charge region.

6. All above characteristics suggest that the electric structure of the thunderstorm was of polarity-inverted, which is differed from the normal dipole charge structure. The polarity-inverted structure of thunderstorm and IC discharges were observed frequently during STEPS [10], [11]. The mechanism of this special phenomenon on the Tibetan Plateau will be further studied.

Acknowledgments. The research is supported by National Natural Science Foundation of China (Grant No. 40325013)

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